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HST-WFPC2 Observations of the Star Clusters in the Giant HII Regions of M33

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Abstract. We present a photometric study of the stars in ionizing star clusters embedded in several giant HII regions of M33 (CC93, IC 142, NGC 595, MA2, NGC 604 and NGC 588). Our photometry are based on the HST-WFPC2 images of these clusters. Color-magnitude diagrams and color-color diagrams of these clusters are obtained and are used for estimating the reddenings and ages of the clusters. The luminosity functions (LFs) and initial mass functions (IMFs) of the massive stars in these clusters are also derived. The slopes of the IMFs range from $\Gamma = -0.5$ to -2.1. It is found interestingly that the IMFs get steeper with increasing galactocentric distance and with decreasing [O/H] abundance.

M33, a spiral galaxy in the Local Group, provides an ideal laboratory to investigate the properties of ionizing star clusters and how much metal abundance affects stellar population at the high-mass end. Interestingly the giant H II regions in M33 are not powered by dense superclusters – as is the case in 30 Doradus, the Antennae and other more distant starbursting systems. Instead, the clusters underlying the giant HII regions in M33 sprawl over 100pc. Two bright clusters NGC 595 and NGC 604 in M33 were studied by Malumuth et al. (1996) and Hunter et al. (1996), respectively.

We have analyzed, using the HSTphot package (Dolphin 2000), the HST-WFPC2 images which were obtained with four filters: F170W, F336W, F439W and F547M for CC93, IC 142, NGC 595, MA2, and NGC 588, and with three filters, F336W, F555W and F814W for NGC 604. Figure 1 shows color-magnitude diagrams of the measured stars in the clusters. It is seen that all the clusters show a prominent blue plume which consists of blue supergiants and massive main sequence stars. The blue plumes extend up to $M_V \approx -8$, indicating that these clusters are very young. We have determined the reddenings for these clusters using the color-color diagrams, obtaining mean values of the reddenings of $E(B-V) = 0.08 - 0.36$.

The ages of the clusters are estimated using the Geneva isochrones (Lejeune & Schaerer 2001). We have adopted the metallicity of these clusters converted from [O/H] of HII regions given by Vilchez et al. (1988). The blue plumes in the clusters in Figure 1 are fit reasonably well by the theoretical isochrones with young ages ranging from 3.2 Myrs to 6.3 Myrs.

We have derived the luminosity functions (LFs) of the stars in the blue plume from the color-magnitude diagrams. For the estimation of the background contribution, we have selected regions located in the WF chip fields. We also have estimated the completeness of our photometry of each cluster using the artificial star experiment with the HSTphot package. The logarithmic slopes of the LFs are found to range from $\alpha = -0.4$ to –0.8. Then the initial mass functions (IMFs) of the massive stars in these clusters are derived from the LFs. The IMFs of these clusters are fit reasonably well by the power laws ($\log \xi \propto \Gamma \log M$). The slopes of the IMFs for the massive stars with $1.0 < \log M < 1.67$ ($10 < M/M_\odot < 46$) are found to vary significantly from $\Gamma = -0.5$ to -2.1.

Figure 2 displays the relations of the slopes of the LFs and IMFs, the galactocentric distance (R/R_0 where $R_0 = 28'$ is a scale length of the disk in M33), and the [O/H] abundance, Figure 2 shows good correlations among them: $\Gamma \propto (-1.64 \pm 0.41)R$, $\Gamma \propto (1.94 \pm 0.83)$[O/H]. It is found that the IMFs of the clusters get steeper with increasing radial distance (and with decreasing [O/H] abundance). This IMF steepening may represent the first strong evidence for a systematic environmental effect on stellar population at the high-mass end. The photoevaporative process provides a viable mechanism for ablating massive protostellar cores and thus steeping the IMF. This result leads to a prediction that the most top-heavy (flattest) IMFs may occur near the centers of star-forming galaxies.

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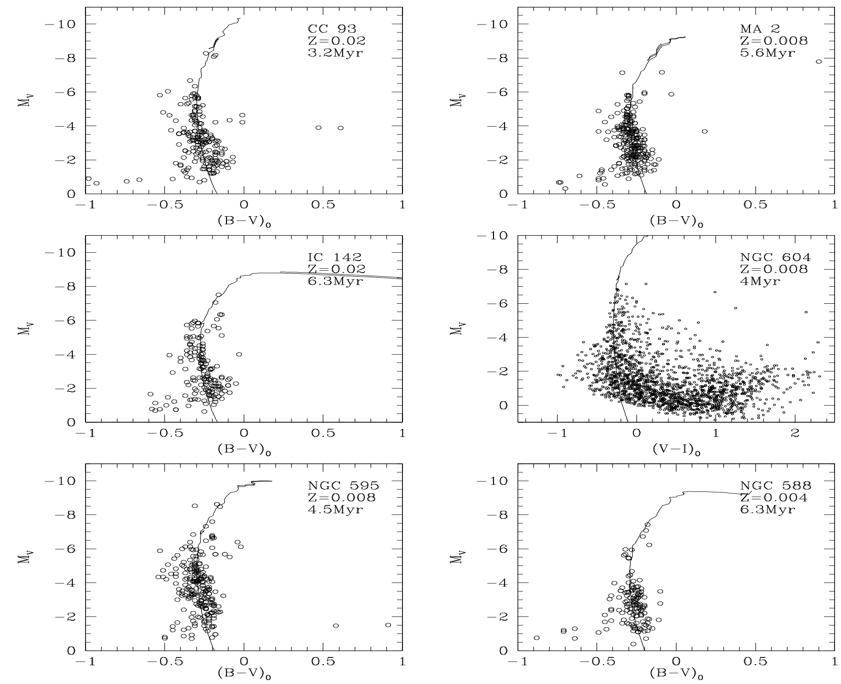

Figure 1. Isochrones (solid lines) fit to the data of the clusters in M33. Corresponding metallicity and age for each cluster are given in the upper right corner of each panel.

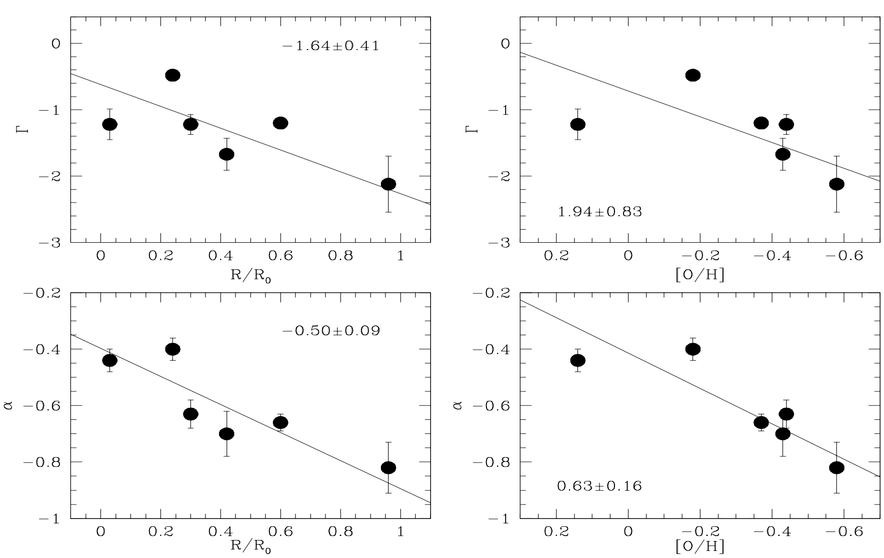

Figure 2. Relations among α (the slope of the luminosity function), Γ (the slope of the stellar IMF), [O/H] (the abundance derived from the HII regions), and the galactocentric distance of the clusters in M33. The solid lines represent linear fits to the data.